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LONG LAKE, ST. JOSEPH COUNTY, MICHIGAN

Pacific Northwest Environmental Research Laboratory

Prepared for:

National Environmental Research Center, Corvallis, Oregon
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16. ABSTRACT
Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivded according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
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REPORT
ON
LONG LAKE
ST. JOSEPH COUNTY
MICHIGAN

EPA REGION V

WORKING PAPER No. 211

WITH THE COOPERATION OF THE

MICHIGAN DEPARTMENT OF NATURAL RESOURCES

AND THE

MICHIGAN NATIONAL GUARD

FEBRUARY, 1975

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FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to fresh water lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point-source discharge reduction and non-point source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's fresh water lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by EPA and to augment plans implementation by the states.

ACKNOWLEDGMENT

The staff of the National Eutrophication Survey (Office of Research & Development, U. S. Environmental Protection Agency) expresses sincere appreciation to the Michigan Department of Natural Resources for professional involvement and to the Michigan National Guard for conducting the tributary sampling phase of the Survey.

A. Gene Gazlay, former Director, and David H. Jenkins, Acting Director, Michigan Department of Natural Resources; and Carlos Fetterolf, Chief Environmental Scientist, and Dennis Tierney, Aquatic Biologist, Bureau of Water Management, Department of Natural Resources, provided invaluable lake documentation and counsel during the course of the Survey. John Vogt, Chief of the Bureau of Environmental Health, Michigan Department of Public Health, and his staff were most helpful in identfying point sources and soliciting municipal participation in the Survey.

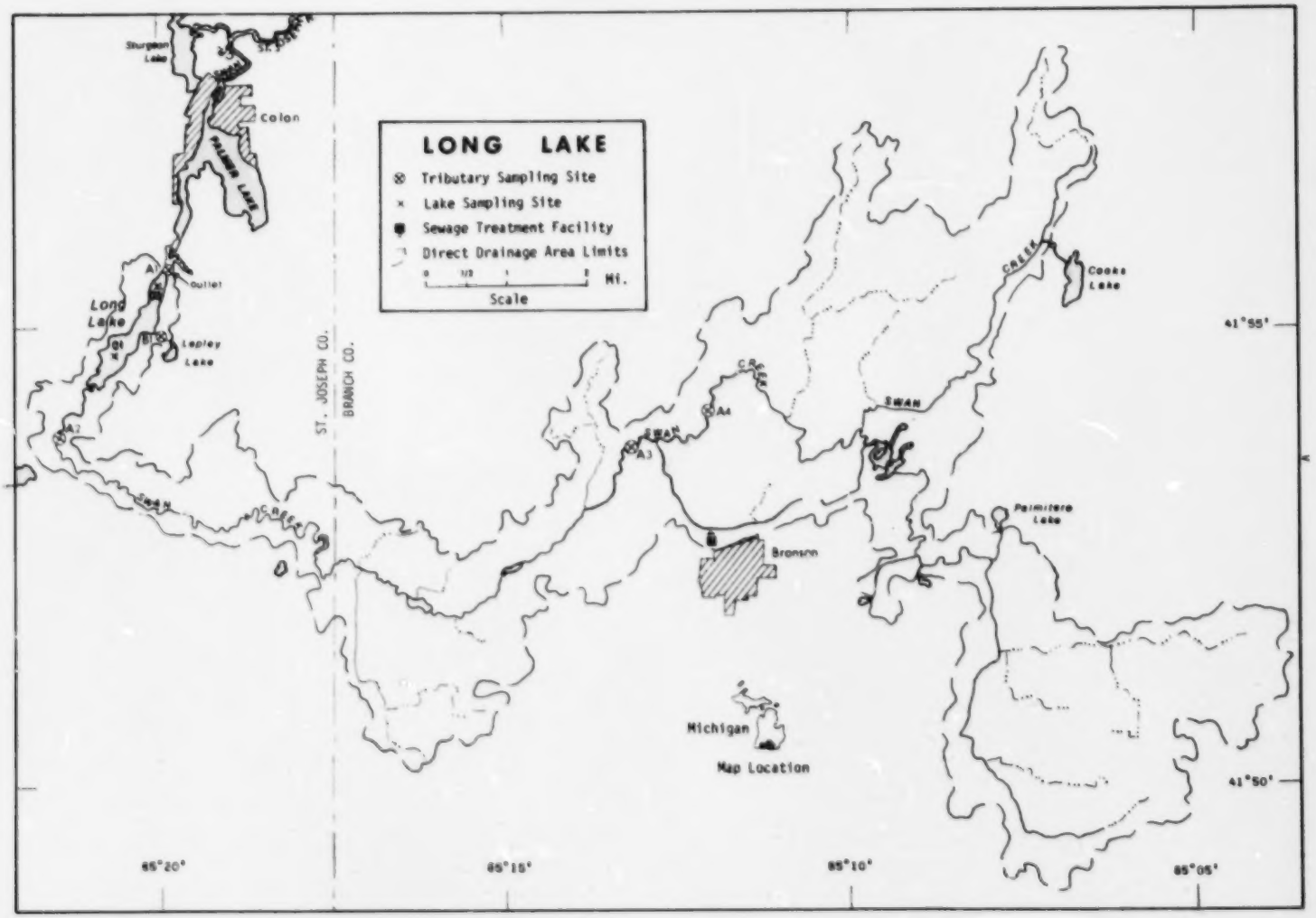
Major General Clarence A. Schnipke (Retired), then the Adjutant General of Michigan, and Project Officer Colonel Albert W. Lesky, who directed the volunteer efforts of the Michigan National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

NATIONAL EUTROPHICATION SURVEY

STUDY LAKES

STATE OF MICHIGAN

LAKE NAME	COUNTY
Allegan Res.	Allegan
Barton	Kalamazoo
Belleville	Wayne
Betsie	Benzie
Brighton	Livingston
Caro Res.	Tuscola
Charlevoix	Charlevoix
Chemung	Livingston
Constantine Res.	St. Joseph
Crystal	Montcalm
Deer	Marquette
Ford	Washtenaw
Fremont	Newago
Higgins	Roscommon
Holloway Res.	Genesee, Lapeer
Houghton	Roscommon
Jordon	Ionia, Barry
Kent	Oakland
Long	St. Joseph
Macatawa	Ottawa
Manistee	Manistee
Mona	Muskegon
Muskegon	Muskegon
Pentwater	Oceana
Pere Marquette	Mason
Portage	Houghton
Randall	Branch
Rogers Pond	Mecosta
Ross	Gladwin
St. Louis Res.	Gratiot
Sanford	Midland
Strawberry	Livingston
Thompson	Livingston
Thornapple	Barry
Union	Branch
White	Muskegon


LONG LAKE
Tributary Sampling Site
Lake Sampling Site
Sewage Treatment Facility
Direct Drainage Area Limits
0 1/2 1 2 Mi.
Scale
Colon
Sturgeon Lake
Long Lake
Outlet
Lepley Lake
ST. JOSEPH CO.
BRANCH CO.
SWAN
CREEK
Cooks Lake
Palmitera Lake
Bronson
Michigan
Map Location
41°55'
41°50'
85°20'
85°15'
85°10'
85°05'

LONG LAKE

STORET NO. 2692

I. CONCLUSIONS

A. Trophic Condition:

Survey data show that Long Lake is eutrophic. Of the 35 Michigan lakes sampled in November, when essentially all were well-mixed, only four had greater mean total and dissolved phosphorus, but 15 had greater mean inorganic nitrogen*.

Survey limnologists observed an algal bloom in progress in June and noted heavy growths of rooted aquatic vegetation in the shallower areas of the lake.

B. Rate-Limiting Nutrient:

The results of the algal assay show that Long Lake was nitrogen limited in September, 1972. The lake data indicate nitrogen limitation at the other sampling times as well.

C. Nutrient Controllability:

1. Point sources--During the sampling year, Long Lake received a total phosphorus load at a rate over three times that proposed by Vollenweider (in press) as "dangerous"; i.e., three times the eutrophic rate (see page 12). Of this load, it is calculated the community of Bronson contributed nearly 76%.

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* See Appendix A.

Reportedly (Eyer, 1973), phosphorus removal facilities were under construction during the 1973 construction season. However, it is evident the facilities were not operational during the Survey sampling year (see data in Appendix D); the phosphorus load from the plant was equivalent to 2.9 lbs/capita/year.

It is calculated that 80% removal of phosphorus at Bronson would reduce the loading to Long Lake to about 16 lbs/acre/yr or 1.82 $g/m^2/yr$. This rate would still exceed the dangerous rate of 1.48 $g/m^2/yr$ but, in view of the relatively short hydraulic retention time of Long Lake, should result in reduced incidence and severity of algal blooms.

2. Non-point sources (see page 11)--It is calculated that non-point sources contributed about 20% of the total phosphorus load during the sampling year. However, the phosphorus exports of the Long Lake tributaries do not appear to be excessive as compared to other Michigan streams sampled.

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS

A. Lake Morphometry†:

1. Surface area: 211 acres.
2. Mean depth: 17 feet.
3. Maximum depth: 32 feet.
4. Volume: 3,587 acre-feet.
5. Mean hydraulic retention time: 31 days.

B. Tributary and Outlet:
(See Appendix B for flow data)

1. Tributaries -

Name	Drainage area*	Mean flow*
Swan Creek	70.8 mi^2	54.7 cfs
Lepley Lake outlet (B-1)	1.2 mi^2	0.9 cfs
Minor tributaries & immediate drainage -	2.6 mi^2	2.2 cfs
Totals	74.6 mi^2	57.8 cfs

2. Outlet -

Swan Creek	74.9 mi^2**	57.9 cfs

C. Precipitation***:

1. Year of sampling: 37.1 inches.
2. Mean annual: 34.1 inches.

† MI Dept. Cons. lake inventory map (1949); mean depth by random-dot method.
* Drainage areas are accurate within ±5%; mean daily flows for 74% of the sampling sites are accurate within ±25% and the remaining sites up to ±40%; and mean monthly flows, normalized mean monthly flows, and mean annual flows are slightly more accurate than mean daily flows.
** Includes area of lake.
*** See Working Paper No. 1, "Survey Methods, 1972".

III. LAKE WATER QUALITY SUMMARY

Long Lake was sampled three times during the open-water season of 1972 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from two stations on the lake and from a number of depths at each station (see map, page v). During each visit a single depth-integrated (15 feet to surface) sample was composited from the stations for phytoplankton identification and enumeration; and during the second visit, a single five-gallon depth-integrated sample was composited for algal assays. Also each time, a depth integrated sample was collected from each of the stations for chlorophyll a analyses. The maximum depths sampled were 20 feet at station 1 and 27 feet at station 2.

The results obtained are presented in full in Appendix C, and the data for the fall sampling period, when the lake essentially was well-mixed, are summarized below. Note, however, the Secchi disc summary is based on all values.

For differences in the various parameters at the other sampling times, refer to Appendix C.

A. Physical and chemical characteristics:

FALL VALUES

(11/12/72)

Parameter	Minimum	Mean	Median	Maximum
Temperature (Cent.)	7.3	7.4	7.4	7.6
Dissolved oxygen (mg/l)	8.4	8.7	8.6	9.0
Conductivity (μmhos)	440	456	460	470
pH (units)	7.7	7.8	7.8	7.8
Alkalinity (mg/l)	184	187	186	190
Total P (mg/l)	0.122	0.163	0.160	0.184
Dissolved P (mg/l)	0.119	0.148	0.141	0.167
NO_2 + NO_3 (mg/l)	0.200	0.300	0.330	0.330
Ammonia (mg/l)	0.350	0.449	0.450	0.500

ALL VALUES

Secchi disc (inches)	36	82	48	144

B. Biological characteristics:

1. Phytoplankton* -

Sampling Date	Dominant Genera	Number per ml
09/17/72	1. Microcystis	3,219
	2. Kirchneriella	832
	3. Lyngbya	723
	4. Oscillatoria	633
	5. Flagellates	416
	Other genera	1,681
	Total	7,504
11/12/72	1. Lyngbya	3,707
	2. Asterionella	416
	3. Fragilaria	217
	4. Synedra	163
	5. Cyclotella	72
	Other genera	253
	Total	4,828

* The June sample was lost in shipment.

2. Chlorophyll a -
(Because of instrumentation problems during the 1972 sampling, the following values may be in error by plus or minus 20 percent.)

Sampling Date	Station Number	Chlorophyll a (µg/l)
06/13/72	01	5.5
	02	6.0
09/17/72	01	22.6
	02	10.6
11/12/72	01	5.1
	02	10.6

C. Limiting Nutrient Study:

1. Autoclaved, filtered, and nutrient spiked -

Spike (mg/l)	Ortho P Conc. (mg/l)	Inorganic N Conc. (mg/l)	Maximum yield (mg/l-dry wt.)
Control	0.176	0.784	17.4
0.010 P	0.186	0.784	17.6
0.020 P	0.196	0.784	18.7
0.050 P	0.226	0.784	19.3
0.050 P + 5.0 N	0.226	5.784	34.4
0.050 P + 10.0 N	0.226	10.784	35.2
10.0 N	0.176	10.784	47.8

2. Discussion -

The control yield of the assay alga, Selenastrum capricornutum, indicates that the potential primary productivity of Long Lake was quite high at the time the sample was collected (09/12/72). Also, the lack of significant increases in yield with increased increments of orthophosphorus, until nitrogen was also added, shows the lake was nitrogen

limited. Note the significant increase in yield when only nitrogen was added.

The lake data indicate nitrogen limitation at all sampling times (N/P ratios were 6/1 or less, and nitrogen limitation would be expected).

IV. NUTRIENT LOADINGS
(See Appendix D for data)

For the determination of nutrient loadings, the Michigan National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page v), except for the high runoff months of March and April when two samples were collected. Sampling began in October, 1972, and was completed in September, 1973.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Michigan District Office of the U.S. Geological Survey for the tributary sites nearest the lake.

In this report, nutrient loads for sampled tributaries were determined by using a modification of a U.S. Geological Survey computer program for calculating stream loadings*. Nutrient loadings for unsampled "minor tributaries and immediate drainage" ("ZZ" of U.S.G.S.) were estimated by using the nutrient loads, in $lbs/mi^2/year$, at station B-1 and multiplying by the ZZ area in mi^2.

The operator of the Bronson wastewater treatment plant provided monthly effluent samples and corresponding flow data. In this report, it is assumed that all of the nutrients from the Bronson STP reached Long Lake during the sampling year.

In the following loading tables, the loads attributed to Swan Creek at station A-2 are those measured there minus the Bronson loads.

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* See Working Paper No. 1.

A. Waste Sources:

1. Known municipal* -

Name	Pop. Served	Treatment	Mean Flow (mgd)	Receiving Water
Bronson	2,300	trickling filter	0.378	Swan Creek

2. Industrial - Unknown

* Eyer, 1973.

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	lbs P/ yr	% of total
a. Tributaries (non-point load) -		
Swan Creek	1,670	19.2
Lepley Lake outlet (B-1)	110	1.3
b. Minor tributaries & immediate drainage (non-point load) -	240	2.8
c. Known municipal STP's -		
Bronson	6,580	75.7
d. Septic tanks* -	60	0.7
e. Industrial - Unknown	-	-
f. Direct precipitation** -	30	0.3
Total	8,690	100.0

2. Outputs -

Lake outlet - Swan Creek 7,890

3. Net annual P accumulation - 800 pounds

* Estimated 100 shoreline dwellings; see Working Paper No. 1.
** See Working Paper No. 1.

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	lbs N/ yr	% of total
a. Tributaries (non-point load) -		
Swan Creek	125,790	76.9
Lepley Lake outlet (B-1)	4,600	2.8
b. Minor tributaries & immediate drainage (non-point load) -	9,970	6.1
c. Known municipal STP's -		
Bronson	18,750	11.5
d. Septic tanks* -	2,350	1.4
e. Industrial - Unknown	-	-
f. Direct precipitation** -	2,030	1.3
Total	163,490	100.0

2. Outputs -

Lake outlet - Swan Creek 175,010

3. Net annual N loss - 11,520 pounds

D. Mean Annual Non-point Nutrient Export by Subdrainage Area:

Tributary	lbs $P/mi^2/yr$	lbs $N/mi^2/yr$
Swan Creek	24	1,777
Lepley Lake outlet (B-1)	92	3,833

* Estimated 100 shoreline dwellings; see Working Paper No. 1.
** See Working Paper No. 1.

E. Yearly Loading Rates:

In the following table, the existing phosphorus loading rates are compared to those proposed by Vollenweider (in press). Essentially, his "dangerous" rate is the rate at which the receiving waters would become eutrophic or remain eutrophic; his "permissible" rate is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic rate would be considered one between "dangerous" and "permissible".

Note that Vollenweider's model may not be applicable to water bodies with very short hydraulic retention times.

	Total Phosphorus		Total Nitrogen	
Units	Total	Accumulated	Total	Accumulated
lbs/acre/yr	41.2	3.8	774.8	loss*
grams/m^2/yr	4.62	0.42	86.8	-

Vollenweider loading rates for phosphorus ($g/m^2/yr$) based on mean depth and mean hydraulic retention time of Long Lake:

"Dangerous" (eutrophic rate)	1.48
"Permissible" (oligotrophic rate)	0.74

* The apparent nitrogen loss may have been due to nitrogen fixation in the lake, resolubilization of previously sedimented nitrogen, or unmeasured ground-water inputs. However, it could also have been due to insufficient outlet sampling in relation to the relatively short hydraulic retention time (note that the mean total N concentration at the Swan Creek outlet, A-1, was 1.495 mg/l; but the mean T-N concentration at the Swan Creek inlet, A-2, was only 1.312 mg/l).

V. LITERATURE REVIEWED

Eyer, Frederick T., 1973. Treatment plant questionnaire (Bronson STP). MI Dept. Publ. Health, Lansing.

Vollenweider, Richard A. (in press). Input-output models. Schweiz. Z. Hydrol.

VI. APPENDICES

APPENDIX A

LAKE RANKINGS

LAKE DATA TO BE USED IN RANKINGS

LAKE CODE	LAKE NAME	ALL VALUES MEAN TOTAL P	ALL VALUES MEAN DISS P	ALL VALUES MEAN INORG N	ALL VALUES 500-MEAN SEC	ALL VALUES MEAN CHLORA	ALL VALUES 15-MIN UO
2640	HOLLOWAY RESERVOIR	0.062	0.043	1.481	439.375	10.670	9.200
2641	CARO RESERVOIR	0.117	0.022	3.035	473.000	11.967	9.500
2642	BOARDMAN HYDRO POND	0.006	0.005	0.358	363.500	1.267	6.600
2643	ALLEGAN LAKE	0.123	0.057	1.168	470.222	20.311	12.600
2646	BARTON LAKE	0.121	0.086	1.489	456.167	27.800	14.850
2649	BELLEVILLE LAKE	0.118	0.048	1.420	465.250	28.262	8.200
2650	BETSIE LAKE	0.025	0.008	0.273	461.667	4.567	7.400
2653	BRIGHTON LAKE	0.109	0.073	1.015	456.000	44.233	7.500
2657	LAKE CHARLEVOIX	0.007	0.006	0.230	351.250	3.008	9.240
2658	LAKE CHEMUNG	0.044	0.014	0.132	484.333	13.483	14.600
2661	CONSTANTINE RESERVOIR	0.027	0.008	0.910	456.167	39.317	7.500
2669	FORD LAKE	0.105	0.058	1.536	456.167	14.733	14.000
2671	FREMONT LAKE	0.372	0.342	1.406	441.667	28.500	14.400
2680	JORDAN LAKE	0.140	0.144	1.998	427.667	20.517	14.900
2683	KENT LAKE	0.040	0.015	0.417	455.000	33.944	13.000
2688	LAKE MACATAWA	0.197	0.120	2.358	477.600	25.600	12.200
2689	MANISTEE LAKE	0.018	0.010	0.304	451.333	6.317	11.300
2694	MUSKEGON LAKE	0.047	0.041	0.469	436.444	9.511	14.800
2695	PENTWATER LAKE	0.027	0.017	0.496	436.667	16.083	14.800
2671	RANDALL LAKE	0.295	0.183	0.818	457.333	27.217	8.020
2672	ROGERS POND	0.026	0.015	0.183	435.500	8.133	9.600
2673	RUSS RESERVOIR	0.034	0.021	0.460	465.333	10.383	8.200
2674	SANFORD LAKE	0.016	0.008	0.387	458.750	13.791	8.300
2683	THORNAPPLE LAKE	0.042	0.032	1.737	442.833	14.650	10.800
2685	UNION LAKE	0.083	0.064	1.252	455.500	15.667	8.200
2688	WHITE LAKE	0.027	0.019	0.367	417.778	9.211	13.400
2691	MONA LAKE	0.307	0.241	0.983	451.667	27.783	14.100
2692	LONG LAKE	0.163	0.148	0.749	418.400	10.067	13.600

LAKE DATA TO BE USED IN RANKINGS

LAKE CODE	LAKE NAME	FALL VALUES MEAN TOTAL P	FALL VALUES MEAN DISS P	FALL VALUES MEAN INORG N	ALL VALUES 500-MEAN SEC	ALL VALUES MEAN CHLORA	ALL VALUES 15-MIN DO
2693	ST LOUIS RESERVOIR	0.134	0.093	1.227	462.667	5.583	8.420
2694	CRYSTAL LAKE	0.009	0.006	0.164	380.000	2.986	13.000
2695	HIGGINS LAKE	0.007	0.005	0.058	268.500	1.043	9.400
2696	HOUGHTON LAKE	0.018	0.008	0.136	420.833	9.217	8.200
2697	THOMPSON LAKE	0.043	0.029	0.436	407.889	11.967	14.800
2698	PERE MARQUETTE LAKE	0.032	0.024	0.346	448.667	11.833	8.600
2699	STRAWBERRY LAKE	0.069	0.050	0.567	419.800	11.117	13.600

PERCENT OF LAKES WITH HIGHER VALUES (NUMBER OF LAKES WITH HIGHER VALUES)

LAKE CODE	LAKE NAME	----------FALL VALUES---------- MEAN TOTAL P	MEAN DISS P	MEAN INORG N	----------ALL VALUES---------- SUR-MEAN SEC	MEAN CHLOA	15-MIN DO	INDEX NO
2640	HULLOWAY RESERVOIR	46 (16)	43 (15)	17 (6)	57 (20)	60 (21)	63 (22)	286
2641	CARO RESERVOIR	29 (10)	54 (19)	0 (0)	3 (1)	49 (17)	54 (19)	189
2642	BOARDMAN HYDRO POND	97 (34)	97 (34)	69 (24)	91 (32)	94 (33)	97 (34)	545
2603	ALLEGAN LAKE	20 (7)	31 (11)	31 (11)	6 (2)	29 (10)	40 (14)	157
2606	BANTON LAKE	23 (8)	20 (7)	14 (5)	29 (9)	14 (5)	3 (1)	103
2609	BELLEVILLE LAKE	26 (9)	37 (13)	20 (7)	11 (4)	11 (4)	79 (26)	184
2610	BETSIE LAKE	77 (27)	77 (27)	80 (28)	17 (6)	86 (30)	94 (33)	431
2613	BRIGHTON LAKE	31 (11)	23 (8)	34 (12)	34 (12)	0 (0)	90 (31)	212
2617	LAKE CHARLEVOIX	91 (32)	91 (32)	83 (29)	94 (33)	89 (31)	60 (21)	508
2618	LAKE CHEMUNG	49 (17)	71 (25)	94 (33)	86 (30)	46 (16)	11 (2)	357
2621	CONSTANTINE RESERVOIR	71 (25)	83 (29)	40 (14)	29 (9)	3 (1)	90 (31)	316
2629	FORD LAKE	34 (12)	29 (10)	11 (4)	29 (9)	37 (13)	23 (8)	163
2631	FREMONT LAKE	0 (0)	0 (0)	23 (8)	54 (19)	9 (3)	11 (2)	97
2640	JORDAN LAKE	11 (4)	11 (4)	6 (2)	69 (24)	26 (9)	0 (0)	123
2643	KENT LAKE	57 (20)	69 (24)	63 (22)	40 (14)	6 (2)	36 (12)	271
2648	LAKE MACATAWA	9 (3)	14 (5)	3 (1)	0 (0)	23 (8)	43 (15)	92
2649	MANISTEE LAKE	80 (28)	74 (26)	77 (27)	46 (16)	80 (28)	46 (16)	403
2659	MUSKEGON LAKE	37 (13)	40 (14)	54 (19)	60 (21)	69 (24)	11 (2)	271
2665	PENTWATER LAKE	69 (24)	63 (22)	51 (18)	66 (23)	31 (11)	11 (2)	291
2671	RANDALL LAKE	6 (2)	6 (2)	43 (15)	23 (8)	20 (7)	86 (30)	184
2672	ROGERS POND	74 (26)	66 (23)	86 (30)	63 (22)	77 (27)	51 (18)	417
2673	RUSS RESERVOIR	60 (21)	57 (20)	57 (20)	9 (3)	63 (22)	79 (28)	325
2674	SANFORD LAKE	86 (30)	80 (28)	74 (26)	20 (7)	43 (15)	71 (25)	374
2683	THORNAPPLE LAKE	54 (19)	46 (16)	9 (3)	51 (18)	40 (14)	49 (17)	249
2685	UNION LAKE	40 (14)	26 (9)	26 (9)	37 (13)	34 (12)	79 (28)	242
2688	WHITE LAKE	66 (23)	60 (21)	66 (23)	80 (28)	74 (26)	31 (11)	377
2691	MONA LAKE	3 (1)	3 (1)	37 (13)	43 (15)	17 (6)	20 (7)	123
2692	LONG LAKE	14 (5)	9 (3)	46 (16)	77 (27)	66 (23)	27 (9)	239

PERCENT OF LAKES WITH HIGHER VALUES (NUMBER OF LAKES WITH HIGHER VALUES)

LAKE CODE	LAKE NAME	FALL VALUES: MEAN TOTAL P	FALL VALUES: MEAN DISS P	FALL VALUES: MEAN INORG N	ALL VALUES: 500-MEAN SEC	ALL VALUES: MEAN CHLORA	ALL VALUES: 15-MIN DO	INDEX NO
2693	ST LOUIS RESERVOIR	17 (6)	17 (6)	29 (10)	14 (5)	83 (29)	69 (24)	229
2694	CRYSTAL LAKE	89 (31)	89 (31)	89 (31)	89 (31)	91 (32)	36 (12)	483
2695	HIGGINS LAKE	94 (33)	94 (33)	97 (34)	97 (34)	97 (34)	57 (20)	536
2696	HOUGHTON LAKE	83 (29)	86 (30)	91 (32)	71 (25)	71 (25)	79 (26)	481
2697	THOMPSON LAKE	51 (18)	49 (17)	60 (21)	83 (29)	51 (18)	11 (2)	305
2698	PERE MARQUETTE LAKE	63 (22)	51 (18)	71 (25)	49 (17)	54 (19)	66 (23)	354
2699	STRAWBERRY LAKE	43 (15)	34 (12)	49 (17)	74 (26)	57 (20)	27 (9)	284

APPENDIX B

TRIBUTARY FLOW DATA

TRIBUTARY FLOW INFORMATION FOR MICHIGAN 2/3/75

LAKE CODE 2692 LONG LAKE

TOTAL DRAINAGE AREA OF LAKE(SQ MI) 74.90

TRIBUTARY	SUB-DRAINAGE AREA(SQ MI)	NORMALIZED FLOWS(CFS) JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
2692A1	74.90	62.20	77.00	84.70	102.00	77.00	50.60	37.80	29.10	25.00	33.40	46.50	70.60	57.86
2692A2	70.80	58.80	72.80	80.20	96.80	72.80	47.90	35.70	27.50	23.60	31.60	43.90	66.80	54.74
2692B1	1.20	1.00	1.23	1.36	1.64	1.23	0.81	0.61	0.47	0.40	0.54	0.74	1.11	0.93
2692Z1	2.90	2.41	2.98	3.28	3.97	2.98	1.96	1.46	1.13	0.97	1.29	1.80	2.74	2.24

SUMMARY

TOTAL DRAINAGE AREA OF LAKE = 74.90
SUM OF SUB-DRAINAGE AREAS = 74.90

TOTAL FLOW IN = 696.51
TOTAL FLOW OUT = 695.90

MEAN MONTHLY FLOWS AND DAILY FLOWS(CFS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
2692A1	10	72	39.00	29	52.00				
	11	72	71.00						
	12	72	89.00	2	70.00	30	106.00		
	1	73	124.00	27	93.00				
	2	73	75.00	20	67.00				
	3	73	112.00	10	90.00	31	142.00		
	4	73	118.00	14	100.00	28	122.00		
	5	73	93.00	12	78.00				
	6	73	100.00	10	133.00				
	7	73	52.00						
	8	73	49.00	26	52.00				
	9	73	30.00	25	26.00				
2692A2	10	72	37.00	29	49.00				
	11	72	67.00						
	12	72	84.00	2	66.00	30	100.00		
	1	73	118.00	27	88.00				
	2	73	71.00	20	64.00				
	3	73	106.00	10	86.00	31	134.00		
	4	73	112.00	14	95.00	28	116.00		
	5	73	88.00	12	74.00				
	6	73	94.00	10	126.00				
	7	73	49.00						
	8	73	46.00	26	49.00				
	9	73	29.00	25	25.00				

LAKE CODE 2642 LONG LAKE

MEAN MONTHLY FLOWS AND DAILY FLOWS(CFS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
269281	10	72	0.60	29	0.80				
	11	72	1.10						
	12	72	1.40	2	1.10	30	1.60		
	1	73	1.90						
	2	73	1.20	3	1.40	20	1.00		
	3	73	1.70	10	1.40	31	2.20		
	4	73	1.50	14	1.60	28	1.90		
	5	73	1.40	12	1.20				
	6	73	1.60	10	2.10				
	7	73	0.80						
	8	73	0.80	26	0.80				
	9	73	0.50	25	0.40				
269277	10	72	1.50						
	11	72	2.70						
	12	72	3.40						
	1	73	4.80						
	2	73	2.90						
	3	73	4.30						
	4	73	4.50						
	5	73	3.60						
	6	73	3.80						
	7	73	2.00						
	8	73	1.90						
	9	73	1.20						

APPENDIX C

PHYSICAL and CHEMICAL DATA

STORET RETRIEVAL DATE 75/02/04

269201
41 54 43.0 085 20 48.0
LONG LAKE
26 MICHIGAN

11EPALES
3

2111202
0020 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00630 NO2&NO3 N-TOTAL MG/L	00610 NH3-N TOTAL MG/L	00665 PHOS-TOT MG/L P	00666 PHOS-DIS MG/L P
72/06/13	15 06	0000	21.0	12.8		440	8.75	184	0.030	0.050	0.041	0.030
	15 06	0010	20.6	11.2		440	8.65	185	0.020	0.040	0.026	0.020
	15 06	0013	16.7	2.6								
	15 06	0015	13.9	1.6		410	7.75	184	0.020	0.070	0.075	0.058
	15 06	0020	11.8	0.0		460	7.65	181	0.070	0.840	0.230	0.221
72/09/17	13 13	0000			36	410	8.60	137	0.040	0.070	0.110	0.031
	13 13	0004	20.0	9.5		420	8.55	138	0.040	0.060	0.081	0.021
	13 13	0015	19.0	5.3		425	7.82	143	0.060	0.460	0.108	0.089
72/11/12	08 55	0000			144	460	7.80	186	0.200	0.500	0.184	0.167
	08 55	0004	7.5	8.6		440	7.80	184	0.330	0.480	0.180	0.166
	08 55	0015	7.6	8.6		440	7.80	185	0.330	0.480	0.182	0.164

DATE FROM TO	TIME OF DAY	DEPTH FEET	32217 CHLRPHYL A UG/L
72/06/13	15 06	0000	5.5J
72/09/17	13 13	0000	22.6J
72/11/12	08 55	0000	5.1J

J VALUE KNOWN TO BE LESS THAN

23

STORET RETRIEVAL DATE 75/02/04

269202
41 55 30.0 085 21 00.0
LONG LAKE
26 MICHIGAN

11EPALES
4

2111202
0025 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00630 NO2&NO3 N-TOTAL MG/L	00610 NH3-N TOTAL MG/L	00665 PHOS-TOT MG/L P	00666 PHOS-DIS MG/L P
72/06/13	15	30 0000	20.8	11.8	48	480	8.60	187	0.040	0.090	0.036	0.034
	15	30 0010	18.7	6.7		500	8.10	193	0.080	0.150	0.078	0.071
	15	30 0015	14.4	1.4				186	0.040	0.140	0.092	0.070
	15	30 0020	12.3	1.6		490	7.70	199	0.120	0.220	0.145	0.145
	15	30 0025	11.8	0.0		500	7.70	188	0.070	0.810	0.304	0.272
72/09/17	13	24 0000			36	430	8.00	145	0.080	0.220	0.123	0.081
	13	24 0004	19.3	6.1		430	7.98	146	0.070	0.210	0.111	0.072
	13	24 0015	18.3	3.5		420	7.68	149	0.080	0.420	0.143	0.115
	13	24 0020	15.2	0.0		460	7.40	175	0.100	1.840	0.464	0.408
	13	24 0027	11.2	0.0		500	7.10	222	0.100	9.140	1.430	1.380
72/11/12	09	10 0000			144	460	7.80	185	0.330	0.430	0.157	0.136
	09	10 0004	7.4	9.0		460	7.80	190	0.290	0.450	0.160	0.141
	09	10 0015	7.4	9.0		460	7.80	189	0.290	0.450	0.157	0.141
	09	10 0023	7.3	8.4		470	7.70	188	0.330	0.350	0.122	0.119

DATE FROM TO	TIME OF DAY	DEPTH FEET	32217 CHLRPHYL A UG/L
72/06/13	15	30 0000	6.6J
72/09/17	13	24 0000	10.6J
72/11/12	09	10 0000	10.6J

J VALUE KNOWN TO BE IN ERROR

APPENDIX D

TRIBUTARY and WASTEWATER TREATMENT PLANT DATA

STORET RETRIEVAL DATE 73/02/04

2692A1 LS2692A1
41 55 30.0 084 20 00.0
SWAN CREEK (LONG LK/PALMER LK CN
26 7.5 COLON
U/LONG LAKE
CO RD BRDG 2 MI SSW OF COLON
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/29	09	20	0.221	1.230	0.460	0.148	0.220
72/12/02	08	40	0.730	0.840	0.067	0.050	0.077
72/12/30	08	59	1.200	1.280	0.060	0.016	0.024
73/01/27	08	20	0.900	0.480	0.030	0.014	0.025
73/02/20	09	00	1.040	1.400	0.052	0.010	0.030
73/03/10	09	10	0.820	0.880	0.105	0.035	0.055
73/03/31	10	30	0.620	0.400	0.044	0.012	0.035
73/04/14	08	50	0.510	0.300	0.031	0.010	0.025
73/04/28	08	27	0.184	0.[illegible]	0.035	0.0058	0.033
73/05/12	07	45	0.019	0.[illegible]	0.[illegible]4	0.013	0.040
73/05/10	07	05	0.011	0.460	0.023	0.033	0.050
73/06/30			0.025	1.130	0.044	0.034	0.130
73/08/25			0.024	1.250	0.022	0.016	0.053
73/09/25	07	30	0.069	1.2[illegible]	0.320	0.052	0.100

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 75/02/04

2692A2 LS2692A2
41 54 00.0 084 21 30.0
SWAN CREEK
26 7.5 COLON
1/LONG LAKE
SECUNDARY RD BRDG .5 MI NE FINDLEY
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00631 NO3+NO2-N TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/24	08	45	0.440	0.730	0.110	0.004	0.084
72/12/02	08	15	0.244	0.420	0.008	0.024	0.036
72/12/30	09	40	1.200	1.500	0.063	0.018	0.032
73/01/27	08	00	1.620	0.440	0.024	0.019	0.030
73/02/20	08	00	1.100	0.710	0.054	0.019	0.040
73/03/10	08	52	0.440	0.710	0.039	0.023	0.040
73/03/31	10	18	0.670	0.420	0.028	0.016	0.035
73/04/14	08	30	0.430	0.840	0.032	0.020	0.037
73/04/28	08	15	0.220	0.540	0.020	0.017	0.043
73/05/12	09	15	0.120	1.010	0.070	0.010	0.033
73/06/10	08	35	0.100	1.110	0.044	0.070	0.120
73/06/30			0.260	0.590	0.033	0.160	0.230
73/08/26			0.150	0.840	0.024	0.110	0.130
73/09/25	07	00	0.340	0.560	0.065	0.049	0.110

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STORET RETRIEVAL DATE 75/02/04

```
 2042AJ          L52642AJ
41 54 00.0 085 13 00.0
SWAN CREEK
25      T.5 BRONSON N
T/LONG LAKE ST JOSEPH CO
CO RD BRDG NW OF BRONSON BELO STP
11EMALES                2111204
4                       0000 FEET  DEPTH
```

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/24	10 00		0.740	0.900	0.184	0.130	0.150
72/12/02	10 33		0.250	0.430	0.136	0.054	0.087
72/12/30	09 26		1.750	2.700	0.154	0.050	0.140
73/01/21	10 20		1.430	0.000	0.050	0.032	0.030
73/02/20	09 30		1.341	0.590	0.113	0.052	0.095
73/03/10	11 10		1.200	0.000	0.069	0.032	0.060
73/03/31	11 10		1.120	0.490	0.692	0.231	0.035
73/04/14	09 45		1.020	0.000	0.075	0.036	0.033
73/04/28	09 35		0.130	0.000	0.050	0.021	0.070
73/05/12	10 30		0.670	0.000	0.030	0.007	0.065
73/06/10	09 50		0.510	1.100	0.110	0.048	0.080
73/07/30			0.450	1.200	0.100	0.073	0.110
73/08/28			0.430	0.490	0.070	0.120	0.130
73/09/25	09 10		0.810	0.000	0.240	0.231	0.200

STORET RETRIEVAL DATE 75/02/04

2777240 L3269284
41 54 00.0 083 12 00.0
SWAN CREEK
CO 1.5 BRUNSON N
1/LUND LAKE ST JOSEPH CO
CO RD 681A 2 MI N BRUNSON ABOV STP TRIB
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	OXYGEN DISSOLVED MG/L	BOD 5 DAY MG/L	NITROGEN TOTAL MG/L	PHOSPHATE ORTHO MG/L P	PHOSPHATE TOTAL MG/L P
72/10/24	09	45	9.8	0.8	0.065	0.009	0.014
72/12/02	10	20	11.3	1.7	0.020	0.003K	0.013
72/12/30	09	20	12.2	1.2	0.073	0.009	0.024
73/01/27	10	15	12.4	0.5	0.031	0.003K	0.013
73/02/20	09	15	12.1	0.4	0.040	0.007	0.015
73/03/10	10	25	11.2	0.5	0.033	0.007	0.020
73/03/31	11	02	12.2	1.0	0.036	0.007	0.023
73/04/14	09	55	10.4	0.8	0.022	0.003	0.010
73/04/28	09	25	9.7		0.023	0.003K	0.020
73/05/12	10	15	9.1	0.5	0.013	0.003K	0.013
73/05/19	09	35	8.8	1.0	0.063	0.013	0.033
73/05/30			8.7	0.9	0.022	0.011	0.023
73/08/26			8.0	0.5	0.017	0.007	0.022
73/09/25	08	00	7.9	0.6	0.030	0.008	0.015

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE [illegible]

[illegible] L32[illegible]
41 55 00.0 088 20 30.0
LEPLEY LAKE/LUND LAKE CONNECTON
.0 [illegible] /.3 COLUN
T/LUND LAKE
SECONDARY RD ANOO 2.5 MI SSW COLUN
11EPALES 2111204
0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	[illegible] NUMBER OF TOTAL MG/L	[illegible] TOT P DIG MG/L	[illegible] PHOS TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/24	09	00	[illegible]	1.[illegible]	[illegible]	0.[illegible]	0.[illegible]
72/12/02	08	31	[illegible]	1.[illegible]	[illegible]	0.[illegible]	0.[illegible]
73/02/01	08	10	1.[illegible]	1.[illegible]	[illegible]	0.[illegible]	0.[illegible]
73/02/20	08	45	1.[illegible]	0.[illegible]	[illegible]	0.[illegible]	0.[illegible]
73/03/10	07	03	1.[illegible]	0.[illegible]	[illegible]	0.[illegible]	0.[illegible]
73/03/31	10	36	1.[illegible]	1.[illegible]	[illegible]	0.[illegible]	0.[illegible]
73/04/14	09	38	[illegible]	[illegible]	[illegible]	0.[illegible]	0.[illegible]
73/04/24	08	21	[illegible]		[illegible]	0.[illegible]	0.[illegible]
73/05/12	09	30	1.[illegible]	1.[illegible]	[illegible]	0.[illegible]	0.[illegible]
73/05/10	08	50	[illegible]	1.[illegible]	[illegible]	0.[illegible]	0.[illegible]
73/05/30			0.[illegible]	0.[illegible]	[illegible]	0.[illegible]	0.[illegible]
73/06/25			[illegible]	1.[illegible]	[illegible]	1.[illegible]	0.[illegible]
73/06/25	07	15	[illegible]	1.[illegible]	[illegible]	[illegible]	[illegible]

< VALUE KNOWN TO BE
LESS THAN INDICATED

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STORET RETRIEVAL DATE 75/02/04

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                                                    269250          18269250      P002300
                                                   41 52 30.0 083 12 00.0
                                                   BRUNSON
                                                   26      7.5 BRUNSON NW
                                                   FLUNG LAKE
                                                   SWAN CREEK
                                                   LIEPALES                      21A1204
                                                   4                             0000 FEET  DEPTH
```

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00623 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P	50050 FLOW RATE INST MGD	50053 CONDUIT FLOW-MGD MONTHLY
73/01/08	09 00								
CP(T)-			1.000	5.100	0.050		3.000	0.578	0.299
73/01/08	15 00								
73/02/08	07 30								
CP(T)-			5.300	7.700	3.004	3.000	3.000	0.408	0.502
73/02/08	15 30								
73/03/06	07 30								
CP(T)-			4.800	10.500	1.100	4.200	5.100	0.408	0.404
73/03/06	15 30								
73/04/25	07 30								
CP(T)-			4.600	8.500	0.005K	2.400	3.300	0.647	0.494
73/04/25	15 30								
73/05/31	07 30								
CP(T)-			6.100	10.750	0.280	3.900	5.400	0.428	0.608
73/05/31	15 30								
73/06/22	07 30								
CP(T)-			7.900	8.400	0.048	4.000	5.000	0.409	0.458
73/06/22	15 30								
73/07/30	07 30								
CP(T)-			7.400	12.000	0.500	4.600	6.000	0.423	0.438
73/07/30	15 30								
73/08/29	07 30								
CP(T)-				10.100	0.200	5.000	7.350	0.294	0.386
73/08/29	15 30								
73/09/26	07 30								
CP(T)-			4.600	11.300	1.320	5.400	8.750	0.251	0.330
73/09/26	15 30								
73/10/04	07 30								
CP(T)-			4.700	15.300	3.000	7.030	11.300	0.252	0.280
73/10/04	15 30								
73/11/27	08 00								
CP(T)-			7.200	15.100	5.000	5.900	10.000	0.247	0.235
73/11/27	16 00								
73/12/27	07 30								
CP(T)-			4.400	15.300	4.200	5.700	8.700	0.251	0.234
73/12/27	15 30								

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 75/02/04

269250 TF269250 P002300
41 52 30.0 085 12 00.0
BRONSON
26 7.5 BRONSON N.
T/LONG LAKE
SWAN CREEK
LIEPALES 2141204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P	50051 FLOW RATE INST MGD	50053 CONDUIT FLOW-MGD MONTHLY
74/01/30 CP(T)- 74/01/30	08 30 15 30		5.300	14.000	0.460	4.400	5.500	0.407	0.240